REMARKS

Applicant respectfully submits that <u>entry of this §1.116 Amendment is proper.</u> Since the amendments above narrow the issues for appeal and merely clarify the subject matter of the claims. Applicant further respectfully submits that such amendments do not raise a new issue requiring a further search and/or consideration by the Examiner. As such, entry of this §1.116 Amendment is earnestly solicited.

Claims 1, 3, and 5-8 remain pending in this application. This Amendment amends claims 1, 3, 5, and 6. No new matter is added to amended claims 1, 3, 5, and 6. Claims 1, 3, 5, and 6 are amended to merely clarify the subject matter of the claims and in no way narrow the scope of the claims in order to overcome the prior art or for any other statutory purpose of patentability.

Notwithstanding any claim amendments of the present Amendment or those amendments that may be made later during prosecution, Applicant's intent is to encompass equivalents of all claim elements. Reconsideration in view of the foregoing amendments and the following remarks is respectfully requested.

Attached is a marked-up version of the changes made to the claims by the Amendment. The attached pages are captioned "**<u>Version with markings to show changes made</u>**".

Claims 1, 3, and 5-8 stand rejected under 35 U.S.C. §103(a) as unpatentable over U.S. Patent No. 6,258,617 B1 to Nitta et al. (hereinafter, Nitta) in view of U.S. Patent 6,046,464 to Schetzina. Claims 1, 3, and 5-8 stand rejected under 35 U.S.C. §103(a) as unpatentable over Nitta in view of U.S. Patent No. 6,072,189 to Duggan.

These rejections are respectfully traversed in view of the following discussion.

I. THE CLAIMED INVENTION

The claimed invention, as described in claim 1, is directed to *inter alia* a group III nitride compound semiconductor device of a successively laminated structure that comprises a substrate, a buffer layer formed directly on the substrate, an intervening layer formed directly on the buffer layer, the intervening layer comprising $In_XGa_{1-X}N$, where $0<X<1$, and a light-emitting layer formed directly on the intervening layer, the light-emitting layer comprising $In_YGa_{1-Y}N$, where $0<Y<1$, in which <u>a first In composition ratio of the intervening</u>

layer, X, changes from a first interface with the buffer layer to a second interface with the light-emitting layer, such that, the first In composition ratio, X, at the second interface becomes substantially equal to a second In composition ratio, Y, of the light-emitting layer.

The claimed invention, as described in claim 3, is directed to *inter alia* a group III nitride compound semiconductor device of a successively laminated structure that comprises a substrate, a buffer layer formed directly on the substrate and having a buffer layer lattice constant, an intervening layer formed directly on the buffer layer, the intervening layer comprising $Al_aGa_bIn_{1-a-b}N$, where $0<a<1$, $0<b<1$, and $a+b<1$; and a light-emitting layer formed directly on the intervening layer, the light-emitting layer comprising $In_YGa_{1-Y}N$, where $0<Y<1$, and having a second layer lattice constant, in which composition ratios of at least Al and In of the intervening layer change from a first interface with the buffer layer to a second interface with the light-emitting layer, such that, a first lattice constant of the intervening layer at the first interface changes to a second lattice constant that is substantially equal to a lattice constant of the light-emitting layer.

An aspect of the present invention allows the composition ratios of a compound semiconductor of an intervening layer, such as, a cladding layer, to change from a first interface with an underlying buffer layer to a second interface with an overlying light-emitting layer.

Another aspect of the present invention allows the composition ratios of the intervening layer at the second interface to be substantially equal to those of composition ratios of the light-emitting layer; thus, providing a second interface, where lattice constants of both the intervening layer and the light-emitting layer are substantially equal to minimize lattice stresses and improve crystallinities of the intervening layer and the light-emitting layer.

Another aspect of the present invention allows the composition ratios of the intervening layer at the first interface to provide a lattice constant that is substantially equal to a lattice constant of the buffer layer; thus, providing a first interface, where lattice stresses are minimized and improving crystallinities of the buffer layer and intervening layers.

Another aspect of the present invention allows control of band gaps by changing the composition ratios of Al and In within the intervening layer and the light-emitting layer.

II. THE PRIOR ART REJECTIONS

A. The Nitta Reference

Nitta discloses a gallium-nitride-based compound semiconductor blue light emitting diode 1 that has a sapphire substrate 100 (col. 2, lines 65-66 and Fig. 1). On the substrate 100, a gallium-nitride-based semiconductor buffer layer 101 and a gallium-nitride-based n-type semiconductor contact layer 102 are formed (col. 2, line 66 to col. 3, line 3). On layer 102, a gallium-nitride-based n-type semiconductor clad layer 103, a gallium-nitride-based semiconductor active layer 104, a gallium-nitride-based p-type semiconductor clad layer 105, and a gallium-nitride-based p-type semiconductor contact layer 106 are formed (col. 3, lines 3-8).

The invention of Nitta employs an InAlGaN compound semiconductor as the gallium-nitride-based semiconductor (col. 3, lines 11-12). The composition of the InAlGaN compound semiconductor is expressed as In(x)Al(y)Ga(1-x-y), where 0<=x<=1, 0<=y<=1, and x+y<=1 (col. 3, lines 15-17).

The gallium-nitride-based n-type semiconductor buffer layer 101 relaxes unconformity between the gallium-nitride-based semiconductor contact layer 102 and the sapphire substrate 100 (col. 3, lines 18-21). Values for the parameters of In(x)Al(y)Ga(1-x-y) are 0<=x<=1 and 0<=y<=1, preferably, 0<=x<=0.5 and 0<=y<=0.5 (col. 3, lines 21-23).

Values for the parameters of In(x)Al(y)Ga(1-x-y) of the gallium-nitride-based n-type semiconductor contact layer 102 are 0<=x<=1 and 0<=y<=1, preferably, 0<=x<=0.3 and 0<=y<=0.3 (col. 3, lines 24-28).

The gallium-nitride-based n-type semiconductor clad layer 103 forms the n side of a p-i-n junction that forms a light emitting region, where values for the parameters of In(x)Al(y)Ga(1-x-y) of the gallium-nitride-based n-type semiconductor clad layer 103 are 0<=x<=1 and 0<=y<=1, preferably, 0<=x<=0.3 and 0.1<=y<=1 (col. 3, lines 31-36).

The gallium-nitride-based semiconductor active layer 104 is substantially an intrinsic semiconductor layer that forms a main part of the light emitting region (col. 3, lines 40-43). Values for the parameters of In(x)Al(y)Ga(1-x-y) are properly adjusted according to a required wavelength of light and are 0<=x<=1 and 0<=y<=1, preferably, 0<=x<=0.6 and 0<=y<=0.5 (col. 3, lines 43-47).

B. The Schetzina Reference

Fig. 3 of Schtzina discloses that an ohmic contact 120 may be formed on one or both sides of the $Al_{1-x}Ga_xN$ cladding (first) layers 114a, 144b (col. 10, lines 48-50). The ohmic contacts 120a, 120b include graded (second) layers 122a, 122b comprised of $Al_{1-y}Ga_yN$ (y=x to y=1) between the $Al_{1-x}Ga_xN$ cladding layers 114a, 114b and the GaN (third) layers 124a and 124b (col. 10, lines 50-53). As shown in Fig. 3, the graded layers 122a, 122b, comprised of $Al_{1-y}Ga_yN$, are doped the predetermined conductivity type and are continuously graded, such that, y=x adjacent to the $Al_{1-x}Ga_xN$ cladding layers 114a, 114b and y=1 adjacent to the GaN layers 124a and 124b (col. 10, lines 54-58). The continuously graded layers 122a, 122b, comprised of $Al_{1-y}Ga_yN$, serve as low resistance electronic links between the $Al_{1-x}Ga_xN$ cladding layers 114a, 114b, the GaN layers 124a and 124b, and external metal electrodes 126a, 126b to the semiconductor device itself (col. 10, lines 58-63).

The continuously graded $Al_{1-y}Ga_yN$ layers 122a and 122b may be linearly graded such that the concentration of gallium increases from y=x at the interface with the $Al_{1-x}Ga_xN$ cladding layers 114a, 114b, to y=1 at the interfaces with the GaN layers 124a, and 124b (col. 10, line 65 to col. 11, line 3). This linear graded profile for the $Al_{1-y}Ga_yN$ layers 122a and 122b, along with the appropriate doping, eliminates the band offsets between the $Al_{1-x}Ga_xN$ cladding layers 114a, 114b, and the GaN layers 124a and 124b, which might otherwise impede the flow of carriers into the active region 112 of the device (col. 11, lines 3-6). Fig. 4B shows the energy band diagram for the bottom n-type portion of the semiconductor device of Fig. 3, which illustrates how the linear grading along with the n-type doping of the $Al_{1-y}Ga_yN$ layer 122b eliminates the conduction band (ε_c) offset between the n-type $Al_{1-x}Ga_xN$ cladding layer 114b and the n-type GaN layer 124b.

Finally, Figs. 7A-7C through 12A-12C show energy band diagrams, which illustrate ohmic contacts between various combinations of Group III-V nitride layers (col. 14, lines 55-57). In particular, Fig. 9 A illustrates an energy band diagram for an n-type GaN layer (which should properly be labeled 124b) and an n-type $In_{1-x}Ga_xN$ cladding layer (which should properly be labeled 114b) with an intervening graded region of n-type $In_{1-y}Ga_yN$ 122b.

Claims 1 and 3 recite at least the features of "wherein a first In composition ratio of said intervening layer, X, changes from a first interface with said buffer layer to a second interface with said light-emitting layer, such that, said first In composition ratio, X, at said

second interface becomes substantially equal to a second In composition ratio, Y, of said light-emitting layer" and "wherein composition ratios of at least Al and In of said intervening layer change from a first interface with said buffer layer to a second interface with said light-emitting layer, such that, a first lattice constant of said intervening layer at said first interface changes to a second lattice constant at said second interface that is substantially equal to a lattice constant of said light-emitting layer," respectively.

Nitta discloses a successively laminated structure comprising substrate 100, a gallium-nitride-based semiconductor buffer layer 101, a gallium-nitride-based n-type semiconductor contact layer 102, a gallium-nitride-based n-type semiconductor clad layer 103, and a gallium-nitride-based semiconductor active layer 104, where the gallium-nitride-based semiconductor of Nitta may be expressed as In(x)Al(y)Ga(1-x-y). However, each of the aforementioned layers of Nitta has a constant predetermined composition ratio, which does not change from one interface of the layer to the other interface of the layer. Thus, Nitta does not provide interfaces between the buffer layer and the intervening layer and between the intervening layer and the light-emitting layer that reduce lattice stresses and improve crystallinities, as does the present invention.

Therefore, Nitta does not teach or suggest "wherein a first In composition ratio of said intervening layer, X, changes from a first interface with said buffer layer to a second interface with said light-emitting layer, such that, said first In composition ratio, X, at said second interface becomes substantially equal to a second In composition ratio, Y, of said light-emitting layer" or "wherein composition ratios of at least Al and In of said intervening layer change from a first interface with said buffer layer to a second interface with said light-emitting layer, such that, a first lattice constant of said intervening layer at said first interface changes to a second lattice constant at said second interface that is substantially equal to a lattice constant of said light-emitting layer," as recited in claims 1 and 3, respectively.

Schetzina discloses ohmic contacts that may be formed on one or both sides of $Al_{1-x}Ga_xN$ cladding layers, each cladding layer having a constant predetermined composition ratio, in an integrated heterostructure of Group III-V nitride compound semiconductors. The ohmic contacts may include linearly graded layers, comprised of $Al_{1-y}Ga_yN$, where the composition ratios vary from y=x to y=1 between the $Al_{1-x}Ga_xN$ cladding layers and the GaN contact layers.

As shown in Fig. 3 of Schetzina, the graded layers, comprised of $Al_{1-y}Ga_yN$, are continuously graded, such that, y=x adjacent to the $Al_{1-x}Ga_xN$ cladding layers and y=1 adjacent to the GaN layers. Thus, Schetzina does not teach or suggest a single layer, such as the claimed invention's intervening layer, that comprises a graded composition ratio between the buffer layer and the light-emitting layer of the laminated structure. In fact, Fig. 3 of Schetzina illustrates a cladding layer 114b of a constant predetermined composition ratio, a continuously graded layer 122b, and a contact layer 124b, all of which intervene between the active light-emitting region 112 and the buffer layer 134. In contrast, the claimed invention uses but one graded layer between the buffer layer and the light-emitting layer, and this one graded layer also provides a second interface between the graded layer and the light-emitting layer, which decreases lattice stress to improve efficiency and crystallinity of the overlying light-emitting layer - a feature not disclosed by Schetzina.

Therefore, Schetzina also fails to teach or disclose "wherein a first In composition ratio of said intervening layer, X, changes from a first interface with said buffer layer to a second interface with said light-emitting layer, such that, said first In composition ratio, X, at said second interface becomes substantially equal to a second In composition ratio, Y, of said light-emitting layer" and "wherein composition ratios of at least Al and In of said intervening layer change from a first interface with said buffer layer to a second interface with said light-emitting layer, such that, a first lattice constant of said intervening layer at said first interface changes to a second lattice constant at said second interface that is substantially equal to a lattice constant of said light-emitting layer," as recited in claims 1 and 3, respectively.

For at least the reasons outlined above, Applicant respectfully submits that Nitta and Schetzina, either individually or in combination, fail to teach or suggest every feature of claims 1 and 3. Accordingly, Nitta and Schetzina, either individually or in combination, fail to render obvious the subject matter of claims 1 and 3, and claims 5-8, which depend from claims 1 and 3, under 35 U.S.C. §103(a). Withdrawal of the rejection of claims 1, 3, and 5-8 under 35 U.S.C. §103(a) as unpatentable over Nitta in view of Schetzina is respectfully solicited.

C. The Duggan Reference

Fig. 7 of Duggan is a schematic diagram of a light-emitting diode structure having the same constituent layers as the structure of Fig. 1, but with the introduction of graded layers 41, 42, 43 and 44 at the interfaces between the (AlGa)N cladding layers 4 and 6 and both the GaN contact layers 3 and 7 and the (InGa)N active layer 5 (col. 7, lines 55-61). Whilst graded layers 41, 42, 43 and 44 are shown at each of these four interfaces in the diagram of Fig. 7, it should be understood that it is also within the scop of Duggan's invention to provide graded layers 42 and 43 only at the interfaces between the (AlGa)N cladding layers 4 and 6 and the (InGa)N active layer 5, no such graded layers being provided in this case at the interfaces between the cladding layers 4 and 6 and the contact layers 3 and 7 (col. 7, line 61 to col. 8, line 1).

As argued above, Applicants respectfully submit that Nitta does not teach or suggest "wherein a first In composition ratio of said intervening layer, X, changes from a first interface with said buffer layer to a second interface with said light-emitting layer, such that, said first In composition ratio, X, at said second interface becomes substantially equal to a second In composition ratio, Y, of said light-emitting layer" or "wherein composition ratios of at least Al and In of said intervening layer change from a first interface with said buffer layer to a second interface with said light-emitting layer, such that, a first lattice constant of said intervening layer at said first interface changes to a second lattice constant at said second interface that is substantially equal to a lattice constant of said light-emitting layer," as recited in claims 1 and 3, respectively.

Duggan does not cure the deficiencies of Nitta. Duggan discloses graded layers located between the (AlGa)N cladding layers and the GaN contact layers, and between the cladding layers and the (InGa)N active light-emitting layer. Thus, Duggan does not teach or suggest a single layer, such as the claimed invention's intervening layer, that comprises a graded composition ratio between the buffer layer and the light-emitting layer of the laminated structure. In fact, Fig. 7 of Duggan illustrates a GaN buffer layer, an n-type GaN contact layer, a graded layer 41, an n-type (AlGa)N cladding layer, another graded layer 42, and an active light-emitting (InGa)N layer. In contrast, the claimed invention uses but one graded layer between the buffer layer and the light-emitting layer to provide a far simpler structure, which provides greater ease and lesser costs of manufacture.

Therefore, Duggan also fails to teach or disclose "wherein a first In composition ratio of said intervening layer, X, changes from a first interface with said buffer layer to a second interface with said light-emitting layer, such that, said first In composition ratio, X, at said second interface becomes substantially equal to a second In composition ratio, Y, of said light-emitting layer" and "wherein composition ratios of at least Al and In of said intervening layer change from a first interface with said buffer layer to a second interface with said light-emitting layer, such that, a first lattice constant of said intervening layer at said first interface changes to a second lattice constant at said second interface that is substantially equal to a lattice constant of said light-emitting layer," as recited in claims 1 and 3, respectively.

For at least the reasons outlined above, Applicant respectfully submits that Nitta and Duggan, either individually or in combination, fail to teach or suggest every feature of claims 1 and 3. Accordingly, Nitta and Duggan, either individually or in combination, fail to render obvious the subject matter of claims 1 and 3, and claims 5-8, which depend from claims 1 and 3, under 35 U.S.C. §103(a). Withdrawal of the rejection of claims 1, 3, and 5-8 as unpatentable over Nitta in view of Duggan under 35 U.S.C. §103(a) is respectfully solicited.

III. CONCLUSION

In view of the foregoing, Applicant submits that claims 1, 3, and 5-8, all the claims presently pending in the application, are patentably distinct over the prior art of record and are in condition for allowance. The Examiner is respectfully requested to pass the above application to issue at the earliest possible time.

Should the Examiner find the application to be other than in condition for allowance, the Examiner is requested to contact the undersigned at the local telephone number listed below to discuss any other changes deemed necessary in a telephonic or personal interview.

The Commissioner is hereby authorized to charge any deficiency in fees or to credit any overpayment in fees to Attorney's Deposit Account No. 50-0481.

Respectfully Submitted,

Date: 4/25/03

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CERTIFICATION OF FACSIMILE TRANSMISSION

I hereby certify that I am filing this Amendment by facsimile with the United States Patent and Trademark Office to Examiner Douglas A. Wille, Group Art Unit 2814 at fax number (703) 872-9319 this 25th day of April 25, 2003.

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